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Computational Model of Greenhouse Gas Emissions of Power Station Boiler Considering Desulphurization

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Abstract

the problem was that computational model of CO2 emission of the power plant boiler was affected by the gypsum - Limestone Wet Flue Gas Desulphurization computational model was rebulided on burning equation. Using gypsum - Limestone WFGD coal-fired utility boiler was calculated and analyzed by a new calculation model. The results showed that the new computational model was applicable to calculation of CO2 emission of the power plant boiler. Adoptive gypsum - Limestone WFGD was more 2（1-η）SO2 than with dry FGD. In the case of operating conditions with 100% load, greenhouse gas emission of the power plant boiler was calculated. Emission was more 8.41t than with dry FGD each hour.

*Keywords:*power station boiler; wet desulphurization; carbon dioxide; computational modeling;

1. Introduction

Presently Emissions of our country's greenhouse gas carbon dioxide occupied the second [1] all over the world. emissions of CO2 of coal-fired power plants accounted for one-quarter that our country's use produced emissions of CO_2. Pollution control of the power industry is an important aspect to reduce atmospheric pollution and strengthen pollution prevention in China. At present Computational Method of greenhouse gas of our Country's boiler mainly was that fuel burning produced greenhouse gases through the burning formula. Limestone - gypsum wet flue gas desulphurization [2~6] device was widely used in the power station along with the increasingly stringent environmental protection requirements. But the device [7~11] produced greenhouse gas in the process of desulphurization. Calculational model of greenhouse gas was affected, because the greenhouse gases produced in the process of desulphurization. Computational model was improved. A typical wet FGD and coal-fired power station was calculated and verified by the new calculation model.

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2. Establish model

2.1 Combustion equation [12] [13]

$$RO_2(1+\beta)+O_2=21 \quad (1)$$

β—Coefficient of fuel properties

RO_2—volume fraction of three atomic gases in flue gas

O_2 —volume fraction of oxygen in flue gas

（2） In the actual combustion process, the fuel was incomplete combusted, combustion equation:

$$RO_2(1+\beta)+O_2+（0.605+\beta）CO=21 \quad (2)$$

（3） Coefficient of fuel properties

Coefficient of fuel properties [14] β is dimensionless number; Expression was:

$$\beta = 2.35\frac{H_{ar}-0.126O_{ar}+0.038N_{ar}}{C_{ar}+0.375S_{ar}} \quad (3)$$

Among：H_{ar}, O_{ar}, N_{ar}, C_{ar}, S_{ar} were hydrogen content, oxygen content, nitrogen content, carbon content and sulfur content of as receive of the fuel.

（4）CO^1_2 formula

$$CO_2^1=\frac{21-[O_2+(0.605+\beta)CO]}{1+\beta}-SO_2 \quad (4)$$

When oxygen, carbon monoxide, sulfur dioxide and fuel characteristics parameters was known in the flue gas The volume fraction of carbon dioxide may be commutated by fuel combustion. According to power plant flue gas flow rate on-line monitoring and adopting standard cubic meters， the mass of carbon dioxide was calculated from the boiler:

$$m^1_{CO_2}=2.857CO_2^1\times N \quad (5)$$

N—flue gas emissions

CO_2^1—The volume fraction of carbon dioxide in flue gas

1.2 Gypsum - limestone flue gas desulphurization equipment [15] was used in the power plant. Emission of CO_2 gas was commutated.

Using gypsum - limestone flue gas desulphurization main reaction is as follows:

①$SO_2 + H_2O \rightarrow H_2SO_3$ absorption

②$CaCO_3 + H_2SO_3 \rightarrow CaSO_3 + CO_2 + H_2O$ neutralization

③$CaSO_3 + 1/2\ O_2 \rightarrow CaSO_4$ oxidation

④$CaSO_3 + 1/2\ H_2O \rightarrow CaSO_3 \cdot 1/2H_2O$ crystal

⑤$CaSO_4 + 2H_2O \rightarrow CaSO_4 \cdot 2H_2O$ crystal

⑥$CaSO_3 + H_2SO_3 \rightarrow Ca(HSO_3)_2$ control PH

It can be seen that in the process of removing sulfur dioxide greenhouse gas carbon dioxide was generated by reactive ①, ②.Environment was resulted in secondary pollution. Meanwhile the calculation of greenhouse gas emission of the boiler also was affected, calculational model of emission of the original greenhouse gas required to be amend.

$$CO_2=\frac{21-[O_2+(0.605+\beta)CO]}{1+\beta}-(2\eta-1)SO_2 \quad (6)$$

The formula contained the efficiency of desulphurization, volume fraction of oxygen and volume fraction of carbon monoxide, volume fraction of sulfur dioxide in flue gas and coefficient of fuel properties.

According to the chemical equation, the formula of computation that greenhouse gas was produced in the process of desulphurization was acquired.

$$m_{CO_2^2} = \frac{11}{16} m_{SO_2} \tag{7}$$

Formula of emission CO_2 of using gypsum - limestone FGD power plant can be expressed as:

$$m_{CO_2} = m_{CO_2^1} + m_{CO_2^2} \tag{8}$$

m_{CO_2} —Using gypsum - limestone FGD power plant emissions of CO_2 gas

$m_{CO_2^1}$ —quality of CO_2 produced by burning fuel

$m_{CO_2^2}$ —as the flue gas desulphurization produced quality of CO_2

2.2 Data verification

The 15 days' operational data was extracted from historical data base of a power plant 1 # unit. This power plant was installed 300MW units, used gypsum - limestone wet FGD and burned Lignite. The element analysis was: C_{ar}=40.45.、H_{ar}=3.08、O_{ar}=10.36、N_{ar}=0.6、S_{ar}=0.15，β=0.105.

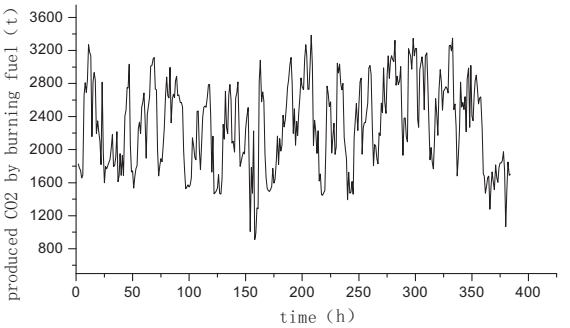

Figure 1 Fuel burning produced CO_2

As shown in Figure 1.The curve that Carbon dioxide was produced by burning fuel was drawed by formula (5) and the actual operating data. In the combustion process, Carbon dioxide content is a value of 2200t / h from fuel combustion. The emission was around 19 million tons each year.

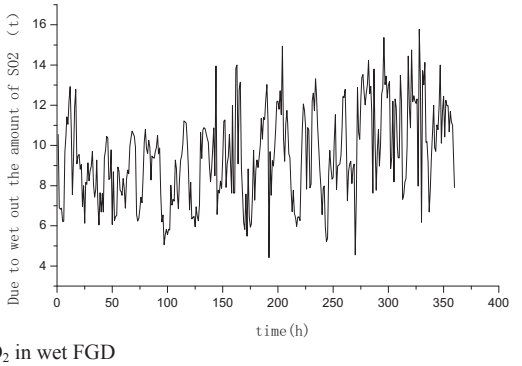

Figure 2 Removal the amount of SO_2 in wet FGD

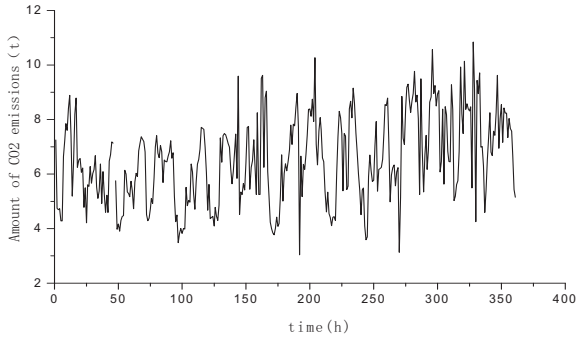

Figure 3 Dry desulphurization process produced the amount of CO_2

As shown in Figure2. According to real-time data, by the wet FGD off SO_2 curve was drawn. According to field data collection and model (7), Figure 3 was drawn. As can be seen that SO_2 may be absorbed by gypsum - limestone flue gas desulphurization from the chart, however, greenhouse gases were produced. As can be seen that emissions of CO2 was 5t / h in the Figure.

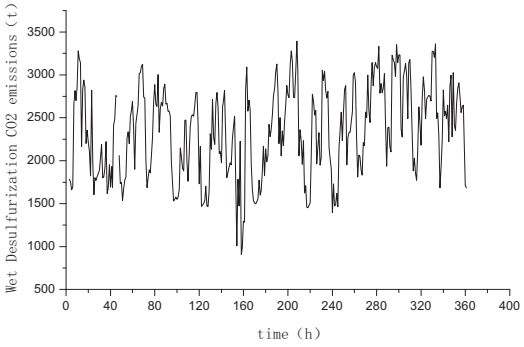

Figure 4 Curve of using wet FGD CO2 emissions

As shown in Figure4. The Figure 4 was drawn by the formula (8) and the actual operation data. An emission of carbon dioxide includes two parts in the using Gypsum — limestone wet FGD plant: fuel combustion and desulphurization. The HCL, HF and $CaCO_3$ react each other in the flue gas, but carbon dioxide production generated a little. The amount of CO2 was ignored.

2.2 Data Analysis

Through the calculation model of greenhouse gas emissions of the original boiler was improved, To calculate greenhouse gas emissions , a new computing model was established in the using gypsum - limestone wet FGD coal-fired power station. The data was being analyzed on the basis of this model

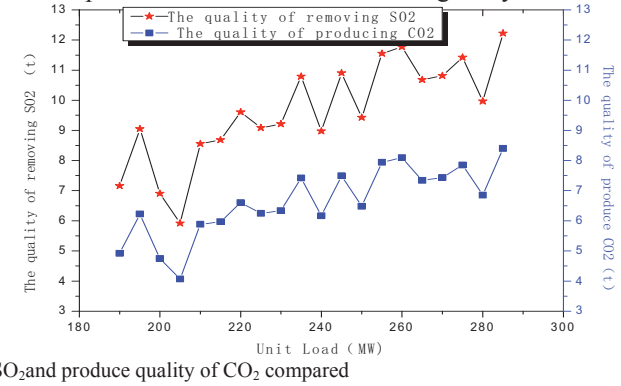

Figure 5 Removal quality of $SO_2$and produce quality of CO_2 compared

As shown in Figure 5, the 1mol SO_2 was removed and the 1mol carbon dioxide was produced at the same time in the process of desulphurization in the event of determined the unit load and using gypsum - limestone wet FGD As its sulfur dioxide absorption grows more, Carbon dioxide emissions will increase . As it's the unit load grows more, flue gas also will increase. In the process of desulphurization carbon dioxide emissions will increase .As the carbon dioxide emission caused great harm to the environment and the greenhouse effect.

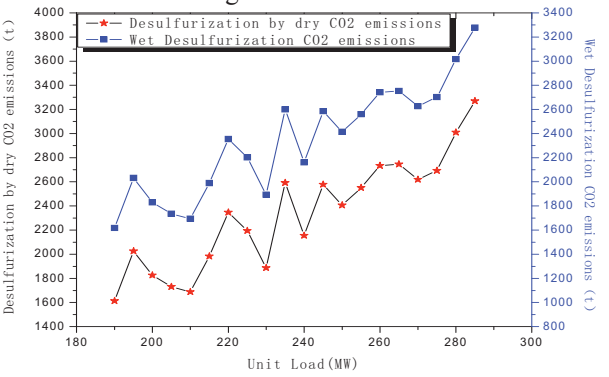

Figure 6 Wet FGD and Dry FGD emission of CO_2 compared

As shown in Figure 6. Through the images can be seen, the gypsum — limestone wet desulphurization was compared with dry FGD; there is still some way to go. In the case of operating conditions with 100% load, Emission was more 8.41t than with dry FGD each hour, unit load in 80%, to 6.16t/h and unit load in 60%, to 4.82t/h. At present, the large-scale coal-fired power station deals with ten thousand tons sulfur dioxide every year. CO2 of considerable amount was generated, and it will cause great impact on the environment, surpass its own regulatory the ability.

3. Error analysis

Next we will examine sulfur dioxide and oxygen have an effect on calculational the amount of carbon dioxide. According to (6) equation:

$$\frac{\partial(CO_2)}{\partial(SO_2)}=2\eta-1+\frac{CO}{(1+\beta)^2}\frac{\partial\beta}{\partial(SO_2)} \tag{9}$$

$$\frac{\partial(CO_2)}{\partial(O_2)}=-\frac{1}{1+\beta}+\frac{CO}{(1+\beta)^2}\frac{\partial\beta}{\partial(O_2)} \tag{10}$$

Coefficient of fuel properties$0<\beta<1$, the following equation is:

$$\frac{\partial(CO_2)}{\partial(SO_2)}=2\eta-1 \qquad \frac{\partial(CO_2)}{\partial(O_2)}=-1$$

According to relational the theory of errors, error of calculation of caused greenhouse gases was:

$\Delta(CO_2)=(2\eta-1)\Delta(SO_2)$； $\Delta(CO_2)=-\Delta(O_2)$

4. Conclusion

(1)On the basis of combustion equation computational model was rebulided for the using gypsum - limestone wet FGD plant. According to new computational model, calculate carbon dioxide emissions. After error analysis, the calculation model is fit for calculating CO_2 emissions for such a power plant.

(2) the gypsum — limestone wet desulphurization was compared with dry FGD, Carbon dioxide emissions was that the former is more than latter .As its the unit load grows more , Carbon dioxide emissions will increase. In the case of operating conditions with60% load, Emission was more 4.82t than with dry FGD each hour, unit load in 80%, to 6.16t/h and unit load in 100%, to 8.41t/h.

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